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Effect of beeswax and chitosan treatments on quality and shelf life of selected mango (*Mangifera indica* L.) cultivars

Abonesh Eshetu [a,b], **Ali M. Ibrahim** [b], **Sirawdink F. Forsido** [b], **Chala G. Kuyu** [b,*]

[a] *Department of Food Science and Postharvest Technology, College of Agriculture and Environmental Science, Arsi University, P.O. Box 193, Assela, Ethiopia*

[b] *Department of Postharvest Management, College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia*

[*] Corresponding author.

E-mail addresses: chalagowe@gmail.com, chala.gowe@ju.edu.et (C.G. Kuyu).

Abstract

Mango is one of the most economically important fruit facing greater problems in storage and transportation to long distance market because of its perishable nature. Evidence suggested that application of edible coatings is a key step to reduce loss of perishable commodities. In line with this, Beeswax and chitosan at different concentrations (0.5%, 1.5% and 2%), and two mango varieties (Apple and Tommy Atkins) were evaluated using completely randomized design (CRD) in three replications. Application of beeswax and chitosan at (2%) significantly reduced physiological weight loss (%), total soluble solid (°Brix), titratable acidity (%), pH, disease incidence (%), disease index (%), maintained Firmness (N) and prolonged shelf-life of fruits compared with untreated control. It was concluded that edible coatings used in the present study have a good potential in maintaining the fruit quality and beeswax at 2% being the most effective treatment on all parameters tested.

Keyword: Food science

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1. Introduction

Mango (*Mangifera indica L.*) as an emerging tropical export fruit is produced in over 90 countries worldwide with a production of over 28.51 million metric tons (Akurugu et al., 2016). Asia accounts for approximately 77% of global mango production. America and Africa account for approximately 13% and 10%, respectively (Kummu et al., 2012). Ethiopia has a diverse agro-ecology that can grow various fruit crops with a huge potential for mango production as well (Berhe et al., 2010). More than 47 thousand hectares of land is under fruit crops in Ethiopia and mangoes cover 12.61% of the fruit crop area (Yeshitela and Nessel, 2003).

Mango fruits are very delicious with an excellent flavour, attractive fragrance and rich in carbohydrates, proteins, fats, minerals, and vitamins particularly vitamin A (beta carotene), vitamin B1, vitamin B2, and vitamin C (ascorbic acid) (Bally, 2006; Talcott et al., 2005). Being rich in bioactive compounds, consumption of mango can provide excellent source of antioxidants that helps to reduce the risk of certain forms of cancer, slow the aging process, improve lung function, and reduce complications associated with diabetes (Alam et al., 2016).

There is a vast potential in internal market for mango in Ethiopia, primarily in dense populated urban areas and in export market as the country is located close to important markets such as Saudi Arabia, Djibouti and Somalia (Workneh et al., 2012). Although Ethiopia has great potential to produce and export high quality mango, the actual yield and quality of the fruits are poor. The reason is partly due to postharvest loss as a result of mishandling of fruits. Considerably high quantity of mango is lost before it reaches the target market or consumers due to poor postharvest handling and limited shelf-life (Debela et al., 2011).

Mango being a highly perishable fruit possesses a very short shelf-life and reach to respiration peak of ripening process on 3rd or 4th day after harvesting at ambient temperature (Narayana et al., 1996). The ripening process of mango fruit involves a series of biochemical reactions, resulting in increased respiration, ethylene production, and degradation of polymers into simpler compounds thus leading to softening of texture (Lalel et al., 2003). Moreover, the shelf life of mango varies among its varieties and depending on storage conditions. It ranges from 4 to 8 days at room temperature and 2−3 weeks in cold storage at 13 °C (Carrillo-Lopez et al., 2000). This short period seriously limits the long distance commercial transport of this fruit (Gomez-Lim, 1997; Hoa et al., 2002). Therefore, in order to meet the demand of this fruit for both internal and export market, it is necessary to address the issue of postharvest loss of mango fruits.

Although satisfactory shelf-life extension has been obtained by use of cold storage, it is costly to implement and needs infrastructure and postharvest facilities. However, the greater proportion of mango is produced by resource poor farmers in remote

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villages where there is no transportation and postharvest facilities which often make them incur high postharvest losses. This motivated the researcher to search for feasible alternative preservation methods. The use of edible coating appears to be a good alternative which, contribute toward expansion of market by increasing the period over which the fruit is transported to internal and external markets. Edible coatings are defined as "a thin application of material that forms a protective barrier around an edible commodity and can be consumed along with the coated product" (Guilbert et al., 1995; McHugh and Senesi, 2000). They are applied directly on the food surface by dipping, spraying or brushing to create a modified atmosphere (McHugh and Senesi, 2000). An ideal coating is defined as one that can extend shelf-life of fresh fruit without causing anaerobiosis and reduces decay without affecting the quality of the fruit (El Ghaouth et al., 1992).

So far, different attempts have been made to evaluate the effectiveness of various edible coating materials in terms of maintaining the freshness and extending the shelf-life of different fruits. Investigations were made on effects of edible chitosan coating on postharvest quality and shelf life of mango fruit (Chien et al., 2007; Zhu et al., 2008). Different coating treatments such as polysaccharide-based composite coating formulations (Kittur et al., 2001), two edible coatings with different permeability (carnauba wax coating and polysaccharide-coating) (Baldwin et al., 1999), four coating formulations contained carnauba wax, shellac, zein, and/or cellulose derivatives (Hoa et al., 2002) and coating waxes (Manzano et al., 1996) have been investigated on mango fruits. Coatings have been used on fresh-cut melon (edible alginate-based coating) (Raybaudi-Massilia et al., 2008), beeswax coatings on sweet orange (Shahid and Abbasi; 2011), edible coatings containing chitosan on carrot sticks (Simões et al., 2009) and sodium alginate and methyl cellulose were applied on peaches (Maftoonazad et al., 2008). It has been shown that losses of fresh produce due to respiration and biochemical reaction during ripening decrease with application of edible coatings. Furthermore, it has been reported that they create a modified atmosphere and reduce weight loss, metabolic activities and protecting microbial attacks during transport and storage (Baldwin, 1994; Tripathi and Dubey, 2004). However, the use of this edible coating material has not yet been reported on fresh mango fruit cultivars produced in Ethiopia and there is no reliable treatment information during handling and storage. To reduce the above stated problems subsistent farmers in Ethiopia can treat fresh mango with edible waxing easily available in their locality such as bee wax and chitosan. This could reduce fruit biochemical change and decay and prolong storage periods on which any scientific investigation have not been done so far in Ethiopia. Therefore, the study aimed to evaluate edible coating materials (beeswax and chitosan) treatments on the quality and shelf-life of selected two mango cultivars produced in Ethiopia.

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2. Materials and methods

2.1. Experimental materials collection

Two mango varieties (Tommy Atkins and Apple) were collected from Melkassa Agricultural Research Centre, Ethiopia. To maintain the uniformity of the experimental materials, only uniform fruits (in terms of overall appearance, size and stage of maturity), free from pest and disease, injuries, bruises and blemishes were selected. Two waxing materials (Beeswax and Chitosan) were obtained from Apiculture and postharvest management laboratories of Jimma University respectively. All other chemicals used for analysis were obtained from postharvest management laboratory of Jimma University and they were analytical grade.

2.2. Experimental materials preparation

The mango fruits were washed using distilled water and surface sterilized by soaking in freshly prepared NaOCl (3% w/v) for 3 minutes and gently rubbed with tidy cotton cloth to remove water. Beeswax emulsion was prepared following the methods indicated in Efendi and Hermawati (2010). Beeswax (76.8 g) was placed in 2L container and melted at 70 °C, heated continuously to attain a temperature of 80−90 °C. Oleic acid (12.8 ml) was added to the melted wax followed by the addition of 25.6 ml triethanolamine (TEA) with a constant stirring. Then 524.8 ml of distilled water (which was pre-heated at the same temperature of 80−90 °C) was added slowly with continued stirring for 5 minutes and air dried. The prepared emulsion was cooled and stored at ambient temperature in sealed container before use.

Preparation of chitosan solution was made following the methods indicated in Wongmetha and Ke (2012). Briefly, 5 g of chitosan powder was dispersed in 850 ml of distilled water to which 50 ml of glacial acetic acid was added to dissolve the chitosan. The pH of the solution was adjusted to 5 with 1 mol/L NaOH, and 1 ml of Tween 80 was added to the solution to improve wettability. After preparation of beeswax emulsion and chitosan solution, they were diluted to different concentrations (0.5%, 1.5% and 2.0%) and used for purpose of waxing the mango fruits.

2.3. Experimental design and treatment application

The experiment was laid out in a completely randomized design (CRD) with factorial arrangements in three replications using Minitab software version 16. The factors consisted of (1) Coating treatments (Control, 0.5% Bw 1.5% Bw, 2% Bw 0.5% Ch 1.5% Ch, 2% Ch), and (2) mango varieties (Apple and Tommy Atkins).

The fruits (36 fruits per replication) were dipped in each concentration of chitosan solution and beeswax emulsion for 5 min. One treatment was used as a control with no application of waxing material. After being air-dried, the fruits were stored

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in cartons at temperature of 22 °C and relative humidity of 65% for quality and shelf life assessments.

2.4. Data collected

Fruits were randomly selected from each experimental unit and data per replication was recorded at 5 days interval for 30 days during the experiment on the following parameters.

2.4.1. Percentage weight loss

Four fruits were marked at the start of experiment from each treatment and kept separate for periodic weighing using digital balance (TWIII, USA) to calculate weight loss during storage and then the percent weight loss were calculated as:

$$\text{Weight loss}(\%) = \frac{\text{Weight of fresh water}(g) - \text{Weight after interval}(g)}{\text{Weight of fresh fruits}(g)}$$

2.4.2. Firmness

Firmness of fruits was measured by destructive or invasive method using computer controlled texture analyzer (TA-XT plus 40555, UK). Samples were subjected to a puncture test at a constant speed of 2 mm/s, using a 2 mm diameter round stainless steel probe. Then the maximum force (N) required to penetrate the sample was recorded and used as the indicator of textural property. Three measurements were made on fruit at different locations (apex, middle and peduncle) and the results were averaged.

2.4.3. Total soluble solids

The total soluble solids content of the fruits was determined using a hand refractometer (Bellinghama + stanley 45-02, UK) and the results were expressed in °Brix.

2.4.4. Titratable acidity and pH

Titratable acidity as percentage of citric acid of fresh tissue was determined following the standard methods (AOAC, 1994). pH of the fruit juice which is the equilibrium measure of hydrogen ion concentration in a juice was measured with a standard calibrated pH meter (CP-50-5).

2.4.5. Disease incidence

Postharvest disease incidence and severity were assessed during storage period. The infection of fungal spoilage and fruits rotten were identified using different approach

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like looking at the appearance of decayed fruits. Following the identification of infections, disease incidence was calculated as number of infected fruits showing any single symptom out of total number of mango fruits sampled (Ogbo and Oyibo, 2008).

$$\text{Percentage of disease incidence} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits Assessed}} * 100$$

2.4.6. Disease severity

The disease severity evaluation was undertaken by observing the record of disease levels according to the infected surface area on the fruits. It was measured on a 1−6 scale in which no infected surface area scored 1, whereas the infected surface areas of >0%−5%, >5%−25%, >25%−50%, >50%−75% and >75% were scored 2, 3, 4, 5 and 6, respectively (Duamkhanmanee, 2008). The percent severity index of fungal infection was then estimated from the numerical ratings of the total samples using the following equation.

$$\text{Percentage severity index} = \frac{\text{Sum of numerical ratings}}{\text{Total number of fruit examined} * \text{maximum grade}} * 100$$

2.4.7. Storage-life

Storage life determination was made following the methods indicated in Garg et al. (2008). Twenty four fruits of each treatment were evaluated during storage and fruits were removed at the first deterioration mark (showing visible wilting). The removal of fruits was carried out until the last fruit became unmarketable (differed according to treatments). The shelf-life index, accounting both the number of fruits possessing marketability and length of storage, was calculated using the following equation.

$$\text{Shelf} - \text{life index} = \frac{1}{N\sum[(n_i - n_{i+1})d_i]}$$

Where, n_i is the number of marketable fruits on i^{th} day; n_{i+1} is the number of marketable fruits on $(i+1)^{th}$ day; N is the total number of fruits under observation; d_i is the number of days after storage.

2.5. Statistical analysis

Statistical analyses were done using SAS version 9.2 (SAS institute Inc, 2008) and analysis of variance (ANOVA) was used to investigate the significant differences in all responses. Diagnostic tools like normal probability plot of the residuals were tested prior to data analysis and indicated that the residuals of all the parameters are normally distributed except for disease incidence, which were arcsine transformed before analysis. Differences between the sample means were conducted using least significant differences (LSD) test.

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3. Results and discussion

3.1. Percent weight loss

Table 1 shows the range of values for percentage weight loss of the mango fruit as affected by variety, waxing materials and their concentration. There was a significant difference ($p < 0.001$) in percent weight loss during storage due to the treatments. The minimum weight loss (12.92%) was recorded for 'Apple' variety treated with 2% beeswax followed by 'Tommy Atkins' variety treated with 2% beeswax (12.95%) on last days of storage. The maximum weight loss was recorded from un-treated control fruits (18.07%) followed by 0.5% chitosan treated fruits (16.07%). There was also a significant difference between the two varieties with minimum and maximum weight losses recorded from 'Tommy Atkins' (14.87%) and 'Apple' (15.28%) varieties respectively (Table 1).

Moreover, the percentage weight loss of all treatments showed an increasing trend with the advancement of the storage period irrespective of treatments and the maximum weight loss was recorded on the last day of storage. However, application of both waxing materials at all concentration significantly ($P < 0.001$) reduced weight loss compared to the control treatments. This might be due to the fact that

Table 1. Effect of treatment with beeswax and chitosan at different concentrations on weight loss (%) of Tommy Atkins and Apple mango fruits.

Variety	Treatment	Days after storage						
		0	5	10	15	20	25	30
Apple	Bw 0.5%	0.00	9.93 ± 0.22^{d}	10.58 ± 0.25^{ef}	11.39 ± 0.25^{c}	12.30 ± 0.21^{c}	13.78 ± 0.22^{cd}	14.99 ± 0.22^{de}
	Bw 1.5%	0.00	8.76 ± 0.3^{f}	10.30 ± 0.15^{ef}	10.90 ± 0.2^{cde}	11.81 ± 0.18^{c}	13.13 ± 0.12^{d}	14.69 ± 0.18^{e}
	Bw 2%	0.00	7.98 ± 0.21^{g}	8.77 ± 0.14^{gh}	9.14 ± 0.20f^{g}	10.01 ± 0.14^{e}	11.10 ± 0.13^{f}	12.92 ± 0.15^{g}
	Ch 0.5%	0.00	10.12 ± 0.3^{b}	11.82 ± 0.33^{bc}	12.63 ± 0.25^{b}	13.68 ± 0.15^{b}	14.58 ± 0.23^{b}	15.85 ± 0.22^{b}
	Ch 1.5%	0.00	9.15 ± 0.23^{c}	11.02 ± 0.12^{de}	12.61 ± 0.15^{b}	13.36 ± 0.23^{b}	14.58 ± 0.15^{b}	15.40 ± 0.19^{c}
	Ch 2%	0.00	9.03 ± 0.13^{ef}	12.47 ± 0.16^{ab}	12.60 ± 0.3^{b}	13.29 ± 0.23^{b}	14.07 ± 0.15^{bc}	15.04 ± 0.3^{cde}
	Control	0.00	10.84 ± 0.2^{a}	13.15 ± 0.25^{a}	14.91 ± 0.35^{a}	15.73 ± 0.20^{a}	16.71 ± 0.32^{a}	18.07 ± 0.25^{a}
Tommy Atkins	Bw 0.5%	0.00	8.80 ± 0.24^{ef}	10.15 ± 0.17^{f}	10.95 ± 0.25^{cd}	11.91 ± 0.27^{c}	13.12 ± 0.22^{d}	14.12 ± 0.16^{f}
	Bw 1.5%	0.00	7.22 ± 0.32^{ij}	8.96 ± 0.22^{g}	9.56 ± 0.25^{f}	10.74 ± 0.15^{d}	12.22 ± 0.25^{e}	13.00 ± 0.16^{g}
	Bw 2%	0.00	7.00 ± 0.13^{j}	7.99 ± 0.18^{h}	8.77 ± 0.12^{g}	9.41 ± 0.16^{e}	10.76 ± 0.22^{f}	12.95 ± 0.18^{g}
	Ch 0.5%	0.00	9.59 ± 0.33^{cd}	11.48 ± 0.15^{cd}	12.83 ± 0.23^{b}	13.54 ± 0.21^{b}	14.68 ± 0.17^{b}	16.07 ± 0.27^{b}
	Ch 1.5%	0.00	7.75 ± 0.14^{gh}	8.98 ± 0.15^{g}	10.39 ± 0.24^{de}	11.14 ± 0.21^{d}	12.37 ± 0.17^{e}	15.18 ± 0.16^{cd}
	Ch 2%	0.00	7.50 ± 0.27^{hi}	10.21 ± 0.17^{f}	10.30 ± 0.23^{e}	10.89 ± 0.12^{d}	12.26 ± 0.22^{e}	15.06 ± 0.17^{cde}
	Control	0.00	9.93 ± 0.35^{bc}	12.52 ± 0.12^{ab}	14.54 ± 0.3^{a}	15.22 ± 0.2^{a}	16.26 ± 0.22^{a}	17.74 ± 0.22^{a}
Cultivars								
	Apple	0.00	9.35 ± 0.28^{a}	11.16 ± 0.25^{a}	12.03 ± 0.25^{a}	12.88 ± 0.32^{a}	13.99 ± 0.2^{a}	15.28 ± 0.22^{a}
	Tommy Atkins	0.00	8.26 ± 0.35^{b}	10.04 ± 0.18^{ab}	11.05 ± 0.15^{b}	11.84 ± 0.25^{b}	13.09 ± 0.21^{b}	14.87 ± 0.21^{b}
Over all	Significance	0.00	**	*	**	**	**	**
	LSD (5%)	0.00	0.3554	0.7916	0.6213	0.6296	0.7154	0.3749
	CV	0.00	0.98	3.27	2.52	2.50	2.48	1.05

Note: Means followed by the same letter(s) are not significantly different, each column was analyzed separately. *: significant. **: highly significant, LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

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waxing materials can cover fruit peel that reduced respiration and transpiration and finally resulted in reduced percent weight loss. Similarly Togrul and Arslan (2004) reported that the coating helps to reduce moisture loss and gaseous exchange from the fruits due to formation of a film on the top of the skin acting as an additional barrier.

The result indicated that beeswax was the most effective at 2% in reducing percentage weight loss for both varieties over the period of storage. This might be attributed to the hydrophobic nature of beeswax than chitosan which acts as barrier for movements of water and other molecules between inner and outer environment of fruits. Similar results were reported by Thai et al. (2002) who showed that wax coating decreased the rate of respiration and transpiration and resulted in reduced weight loss, shriveling and increased shelf-life. The works by Chien et al. (2007) and Zhu et al. (2008) reveal that applying a chitosan coating effectively prolongs the quality attributes and extends the shelf life of mango fruit. Baldwin et al. (1999) also observed that the carnauba wax coating significantly reduced water loss compared to uncoated and polysaccharide-coating treatments of mango fruits.

3.2. Firmness

Table 2 shows the range of values for firmness of the mango fruit as affected by variety, waxing materials and their concentrations. There was a significant difference ($p < 0.001$) in fruit firmness during storage due to the treatments. The firmness showed a decreasing pattern with the advancement of the storage period and the change being faster for untreated fruits than in any other treatments. The faster changes observed from untreated control might be as a result of enhanced ripening that lead to early softening. Fruit softening is associated with the processes of solubilization of pectic substances; break down of starch to soluble sugars and loss of water from peel (Mebratie et al., 2015). Application of 2% beeswax was the most effective treatment resulting in higher firmness values throughout the storage period than all the rest treatments.

Moreover there was a significant difference between the two varieties of mango throughout the storage period. The difference observed between varieties might be associated with tissue structural and compositional differences that determine migration of moisture from tissue and softening of the fruits. The loss of firmness of all treatments showed decreasing trend with an increase in concentration of both edible coatings. This might be due to barrier properties of edible coatings towards O_2 as a physical barrier decreases respiration rate of the fruits. The reduction in respiration rate in turn reduced the activities of hydrolysis enzymes and retarded the softening of mango. In similar manner Baez-Sanudu et al. (2009) reported that high concentrations of wax coating had strong effect on retention of banana firmness.

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Table 2. Effect of beeswax and chitosan treatment on the firmness (N) of Tommy Atkins and Apple mango fruits.

Variety	Treatments	Days after storage						
		0	5	10	15	20	25	30
Apple	Bw 0.5%	24.44 ± 0.22^{g}	20.56 ± 0.17^{efg}	18.28 ± 0.22^{fg}	16.03 ± 0.2^{efg}	13.44 ± 0.25^{ef}	11.22 ± 0.15^{def}	9.81 ± 0.22^{ef}
	Bw 1.5%	30.74 ± 0.12^{cd}	27.54 ± 0.15^{b}	25.03 ± 0.22^{b}	22.97 ± 0.28^{b}	20.86 ± 0.22^{b}	18.55 ± 0.28^{ab}	17.43 ± 0.28^{ab}
	Bw 2%	35.6 ± 0.13^{a}	32.60 ± 0.28^{a}	30.08 ± 0.17^{a}	28.20 ± 0.14^{a}	24.27 ± 0.28^{a}	21.52 ± 0.22^{a}	18.86 ± 0.15^{a}
	Ch 0.5%	27.55 ± 0.34^{ef}	24.24 ± 0.25^{cd}	21.29 ± 0.14^{ed}	19.27 ± 0.14^{cde}	16.59 ± 0.17^{cde}	14.48 ± 0.14^{cde}	12.00 ± 0.2^{cde}
	Ch 1.5%	28.78 ± 0.32^{de}	23.94 ± 0.17^{cd}	22.78 ± 0.2^{bcd}	20.11 ± 0.16^{bcd}	17.67 ± 0.2^{bcd}	14.86 ± 0.22^{bcd}	13.19 ± 0.22^{cd}
	Ch 2%	36.51 ± 0.33^{a}	31.65 ± 0.21^{a}	29.24 ± 0.17^{a}	27.02 ± 0.28^{a}	19.22 ± 0.3^{bcd}	16.58 ± 0.22^{bc}	14.52 ± 0.28^{bc}
	Control	26.09 ± 0.27^{fg}	17.80 ± 0.12^{gh}	14.80 ± 0.22^{h}	12.67 ± 0.22^{gh}	9.33 ± 0.13g	7.33 ± 0.15^{fg}	4.67 ± 0.23^{g}
Tommy Atkins	Bw 0.5%	24.41 ± 0.17^{g}	19.79 ± 0.14^{fg}	17.81 ± 0.14^{g}	15.65 ± 0.18^{fg}	12.71 ± 0.22^{f}	10.78 ± 0.17^{ef}	8.75 ± 0.22^{f}
	Bw 1.5%	27.40 ± 0.17^{ef}	23.31 ± 0.11^{de}	21.3 ± 0.28^{def}	18.75 ± 0.17^{cdef}	16.27 ± 0.28^{de}	13.93 ± 0.15^{cde}	11.85 ± 0.2^{cdef}
	Bw 2%	33.59 ± 0.28^{b}	27.82 ± 0.15^{b}	25.30 ± 0.16^{b}	22.92 ± 0.22^{b}	19.82 ± 0.25^{bc}	17.30 ± 0.28^{bc}	14.14 ± 0.25^{c}
	Ch 0.5%	26.60 ± 0.13f	21.30 ± 0.17^{def}	19.20 ± 0.2^{efg}	16.71 ± 0.23^{def}	14.15 ± 0.28^{ef}	11.74 ± 0.22^{de}	10.18 ± 0.3^{def}
	Ch 1.5%	27.70 ± 0.14^{ef}	23.94 ± 0.14^{cd}	21.96 ± 0.2^{cde}	19.65 ± 0.28b^{cd}	16.73 ± 0.22^{cde}	14.08 ± 0.17^{cde}	11.93 ± 0.2^{cdef}
	Ch 2%	31.03 ± 0.25^{c}	26.71 ± 0.17^{bc}	24.45 ± 0.22^{bc}	21.93 ± 0.22^{bc}	18.85 ± 0.17^{bcd}	15.95 ± 0.22^{bc}	13.65 ± 0.22^{c}
	Control	20.81 ± 0.24^{h}	15.71 ± 0.14^{h}	12.08 ± 0.28^{h}	9.33 ± 0.28^{h}	7.33 ± 0.32^{g}	5.33 ± 0.16^{g}	3.67 ± 0.28^{g}
Cultivars								
	Apple	29.96 ± 0.15^{a}	25.47 ± 0.14^{a}	23.07 ± 0.16^{a}	20.90 ± 0.15^{a}	17.34 ± 0.15^{a}	14.94 ± 0.17^{a}	12.93 ± 0.14^{a}
	Tommy Atkins	27.36 ± 0.22^{b}	22.65 ± 0.22^{b}	20.26 ± 0.25^{b}	17.85 ± 0.24^{b}	15.12 ± 0.18^{b}	12.73 ± 0.24^{b}	10.59 ± 0.22^{b}
Over all	Significance	**	**	*	*	*	*	*
	LSD (5%)	2.0286	3.22	2.9467	3.5631	3.3359	3.939	3.201
	CV	2.57	3.96	4.24	5.63	6.61	8.43	8.25

Note: Means followed by the same letter(s) are not significantly different, each column was analyzed separately. *: significant. **: highly significant, LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

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3.3. Total soluble solids

The effect of edible coating on the total soluble solids content of mango is shown in Table 3 as affected by variety, waxing materials and their concentration. There was a significant difference ($p < 0.001$) in total soluble solids during storage due to the treatments. Total soluble solid value of the mango fruits at the start of the experiment ranged from 6.8 to 9.27^{o}Brix and showed an increasing trend with the advancement of the storage period irrespective of treatments. The results are generally in agreement with previous findings that the amount of sugars usually increases along with fruit ripening through biosynthesis processes or degradation of polysaccharides (Bassetto et al., 2005). Similar observation was also made by Carrillo-Lopez et al. (2000) who reported that 'Haden' mango in coated and uncoated form had an increasing trend of total soluble solids with the passage of storage time and reached a peak after16-24 days.

There was a significant difference among the coating treatments and of the two varieties throughout the storage period. The mango fruits that were coated with 2% beeswax recorded lower contents of total soluble solids than all other treatments. In contrary, untreated control sample recorded the highest total soluble solids than any other treatments throughout the storage period. The faster change observed in TSS (total soluble solid) value of untreated control might be attributed to enhanced ripening rate as a result of ethylene action which accelerated in the presence of excess oxygen.

All treatments coated with both beeswax and chitosan significantly delayed the increasing rate of the total soluble solids content. Although there is significant difference among fruits before application of the coating (at zero day), there is faster increasing trends for control treatments than coated fruits in terms of TSS. The variation observed among the fruits before coating could be correlated to varietal difference since two variety of mango were investigated. The delay in TSS content upon coating application could be related with the oxygen barrier property of edible coating and reduction of respiration as a result. Similar observation was reported by Yonemoto et al. (2002) who explained that lower levels of total soluble solids in fruits coated with chitosan may be due to protective oxygen barrier that reduces oxygen supply to the fruit surface which in turn inhibited respiration. Sharafat et al. (1990) also observed that as storage is prolonged, the rate of respiration, transpiration and other metabolic changes are increased in control fruits in comparison with edible coated mango fruits. Kittur et al. (2001) also observed similar trends with the present study and stated Chitosan-based coatings were much superior in prolonging the shelf-life and quality of banana and mango than polysaccharide-based composite coating formulations.

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Table 3. Effect of beeswax and chitosan treatment on total soluble solids content of Tommy Atkins and Apple mango fruits.

Variety	Treatments	Days after storage						
		0	5	10	15	20	25	30
Apple	Bw 0.5%	7.50 ± 0.22^{ef}	8.73 ± 0.19^{b}	9.77 ± 0.12^{c}	10.77 ± 0.2^{cd}	10.99 ± 0.21^{cde}	12.66 ± 0.12^{de}	14.14 ± 0.22^{cd}
	Bw 1.5%	7.20 ± 0.14^{fg}	$8.5^{b} \pm 0.18^{c}$	9.20 ± 0.2^{de}	9.96 ± 0.15^{de}	10.59 ± 0.21^{def}	12.26 ± 0.22^{e}	13.07 ± 0.15^{g}
	Bw 2%	7.20 ± 0.12^{fg}	8.3 ± 0.22^{bc}	8.92 ± 0.21^{ef}	9.74 ± 0.17^{def}	10.54 ± 0.15^{def}	12.21 ± 0.15^{f}	12.42 ± 0.25^{h}
	Ch 0.5%	8.87 ± 0.23^{ab}	8.73 ± 0.19^{b}	9.74 ± 0.22^{c}	10.77 ± 0.31^{c}	11.51 ± 0.15^{c}	13.51 ± 0.14^{c}	14.52 ± 0.22^{c}
	Ch 1.5%	8.47 ± 0.16^{bc}	8.23 ± 0.15^{bc}	9.33 ± 0.25^{d}	10.11 ± 0.22^{de}	11.32 ± 0.23^{cd}	13.32 ± 0.15^{cd}	14.29 ± 0.22^{cd}
	Ch 2%	8.23 ± 0.20^{bc}	8.00 ± 0.16^{cd}	9.01 ± 0.2^{def}	9.75 ± 0.22^{def}	10.47 ± 0.22^{ef}	12.47 ± 0.15^{e}	13.50 ± 0.25^{efg}
	Control	8.20 ± 0.13^{bcd}	10.5 ± 0.16^{a}	12.06 ± 0.2^{a}	12.79 ± 0.23^{a}	14.25 ± 0.17^{a}	16.25 ± 0.22^{a}	17.43 ± 0.24^{a}
Tommy Atkins	Bw 0.5%	7.40 ± 0.15^{efg}	8.37 ± 0.15^{bc}	9.27 ± 0.15^{de}	10.05 ± 0.25^{de}	10.83 ± 0.23^{cde}	12.50 ± 0.15^{e}	13.99 ± 0.22^{df}
	Bw 1.5%	7.08 ± 0.14^{fg}	8.07 ± 0.22^{cd}	8.92 ± 0.13^{ef}	9.75 ± 0.15^{def}	10.32 ± 0.13^{ef}	12.32 ± 0.22^{e}	13.14 ± 0.15^{g}
	Bw 2%	6.80 ± 0.18^{g}	7.63 ± 0.23^{d}	8.33 ± 0.17^{g}	9.18 ± 0.16^{f}	9.79 ± 0.16^{f}	11.48 ± 0.20^{f}	11.99 ± 0.25^{h}
	Ch 0.5%	9.27 ± 0.15^{a}	8.60 ± 0.13^{b}	9.95 ± 0.18^{c}	10.25 ± 0.15^{cd}	10.98 ± 0.15^{cde}	12.65 ± 0.25^{de}	14.02 ± 0.22^{cd}
	Ch 1.5%	8.23 ± 0.12^{bcd}	8.43 ± 0.15^{bc}	9.02 ± 0.2^{def}	10.05 ± 0.17^{de}	10.73 ± 0.2^{cde}	12.73 ± 0.15^{de}	13.79 ± 0.25^{def}
	Ch 2%	8.07 ± 0.15^{cde}	8.07 ± 0.12^{cd}	8.7 ± 0.21^{f}	9.59 ± 0.18^{ef}	10.51 ± 0.25^{def}	12.51 ± 0.16^{e}	13.36 ± 0.15^{fg}
	Control	7.57 ± 0.14^{def}	10.41 ± 0.2^{a}	11.27 ± 0.2^{b}	12.14 ± 0.15^{b}	12.95 ± 0.16^{b}	14.95 ± 0.25^{b}	15.89 ± 0.16^{b}
Cultivars								
	Apple	7.96 ± 0.14^{a}	8.71 ± 0.15^{a}	9.72 ± 0.22^{a}	10.48 ± 0.17^{a}	11.38 ± 0.12^{a}	13.24 ± 0.16^{a}	14.20 ± 0.25^{a}
	Tommy Atkins	7.77 ± 0.22^{a}	8.5 ± 0.15^{b}	9.34 ± 0.16^{b}	10.14 ± 0.22^{b}	10.87 ± 0.15^{b}	12.74 ± 0.17^{b}	14.20 ± 0.15^{a}
Over all	Significance	Ns	*	**	*	**	*	**
	LSD (5%)	0.6955	0.5164	0.3955	0.5812	0.809	0.6951	0.5216
	CV	4.33	1.15	1.01	1.54	1.62	2.54	1.03

Note: Means followed with the same letter(s) are not significantly different, each column was analyzed separately. Ns: not significant,*: significant ($p < 0.05$), **: highly significant ($p < 0.001$), LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

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3.4. Titratable acidity and pH

The effect of edible coating on the titratable acidity of mango is depicted in Table 4. There was a significant difference ($p < 0.001$) in fruit titratable acidity during storage due to the treatments.

The maximum value of titratable acidity (0.11%) was recorded for mango fruits treated with 2% beeswax and 2% chitosan in both variety and the minimum value (0.02%) was recorded for the control treatment at the end of the storage. This may indicate the fact that fruit coating at higher concentration retarded the respiration rate of the fruits and thus rate of utilization of the respiratory substrates such as organic acids was so minimal. Tefera et al. (2008) similarly stated that lower fruit acidity due to postharvest treatments that delay respiration could be a result of the reduced utilization rate of respiratory substrates such as organic acids.

The titratable acidity decreased with increased storage time in all coated and control fruits. This could be as a result of respiration which utilizes organic acid as respiratory substrates. Doreyappa and Huddar (2001) reported a similar pattern in different varieties of mango fruits stored at temperature of 18−34 °C.

There was a significant difference ($p < 0.001$) in fruit pH during storage due to the treatments. The maximum value of pH between treatments was recorded (5.15) in 'Apple' mango coated by 0.5% chitosan and the minimum pH value (4.00) was recorded for 'Apple' mango coated with 2% of beeswax at the end of storage time. The minimum and maximum pH value of 'Tommy Atkins' was 4.25 and 5.00 in the fruit treated by 0.5% and 1.5% chitosan respectively, while 6.20 value was recorded for control treatment at the end of storage time. The minimum and maximum values of pH values was 4.51 and 4.82% recorded between 'Tommy Atkins' and 'Apple' fruits respectively and there were significant differences between varieties.

Table 5 shows the ranges of pH values as affected by variety, waxing materials and their concentrations. The pH generally increased steadily over the storage period irrespective of treatments. This could be due to degradation of organic acid during respiration as substrate. The results are in agreement with the findings reported by Wani et al. (2014) in that as the storage period or ripening process advances, total acidity could decrease resulting in increase in fruit pH. Doreyappa and Huddar (2001) also reported similar pattern in different varieties of mango fruits stored at 18−34 °C.

3.5. Disease incidence

The effect of edible coating on the disease incidence of mango is depicted in Table 6. There was a significant difference ($p < 0.001$) in disease incidence during storage due to the treatments. The maximum average disease incidence (100%) was

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Table 4. Effect of beeswax and chitosan treatment on the titratable of Apple and Tommy Atkins mango fruits.

Variety	Treatment	Days after storage						
		0	5	10	15	20	25	30
Apple	Bw 0.5%	0.35 ± 0.12^{cd}	0.33 ± 0.14^{b}	0.29 ± 0.12^{a}	0.21 ± 0.25^{ab}	0.18 ± 0.16^{ab}	0.07 ± 0.15^{ef}	0.05 ± 0.25^{defg}
	Bw 1.5%	0.34 ± 0.14^{cd}	0.32 ± 0.12^{bc}	0.22 ± 0.15^{bc}	0.15 ± 0.15^{de}	0.11 ± 0.14^{ef}	0.09 ± 0.15^{cde}	0.07 ± 0.14^{cde}
	Bw 2%	0.36 ± 0.13^{bc}	0.32 ± 0.15^{bc}	0.23 ± 0.14^{bc}	0.18 ± 0.12^{bcd}	0.14 ± 0.17^{cde}	0.14 ± 0.12^{a}	0.11 ± 0.12^{a}
	Ch 0.5%	0.31 ± 0.15^{cde}	0.30 ± 0.13^{bcd}	0.28 ± 0.15^{a}	0.21 ± 0.15^{ab}	0.15 ± 0.12^{bcd}	0.12 ± 0.15^{ab}	0.08 ± 0.15^{bcd}
	Ch 1.5%	0.43 ± 0.17^{ab}	0.41 ± 0.13^{a}	0.28 ± 0.13^{a}	0.21 ± 0.12^{ab}	0.17 ± 0.12^{abc}	0.11 ± 0.15^{bc}	0.10 ± 0.14^{ab}
	Ch 2%	0.44 ± 0.16^{a}	0.41 ± 0.15^{a}	0.30 ± 0.12^{a}	0.23 ± 0.14^{a}	0.19 ± 0.15^{a}	0.12 ± 0.25^{ab}	0.11 ± 0.25^{a}
	Control	0.26 ± 0.12^{ef}	0.25 ± 0.17^{cde}	0.17 ± 0.13^{de}	0.13 ± 0.14^{ef}	0.10 ± 0.17^{fg}	0.07 ± 0.14^{ef}	0.04 ± 0.12^{fgh}
Tommy Atkins	Bw 0.5%	0.23 ± 0.13^{fg}	0.21 ± 0.14^{ef}	0.18 ± 0.14^{de}	0.13 ± 0.12^{ef}	0.10 ± 0.15^{fg}	0.07 ± 0.15^{ef}	0.05 ± 0.25^{defg}
	Bw 1.5%	0.29 ± 0.13^{def}	0.26 ± 0.12^{cde}	0.19 ± 0.1^{cde}	0.16 ± 0.15^{de}	0.13 ± 0.14^{def}	0.09 ± 0.16^{cde}	0.06 ± 0.14^{cdef}
	Bw 2%	0.29 ± 0.14^{cdef}	0.27 ± 0.15^{bcde}	0.29 ± 0.15^{a}	0.22 ± 0.15^{a}	0.19 ± 0.16^{a}	0.14 ± 0.14^{a}	0.11 ± 0.15^{a}
	Ch 0.5%	0.22 ± 0.15^{fg}	0.21 ± 0.16^{ef}	0.20 ± 0.13^{cd}	0.13 ± 0.14^{ef}	0.10 ± 0.14^{fg}	0.09 ± 0.12^{cde}	0.06 ± 0.25^{cdef}
	Ch 1.5%	0.24 ± 0.12^{efg}	0.23 ± 0.17^{e}	0.20 ± 0.12^{cd}	0.17 ± 0.12^{cde}	0.14 ± 0.12^{cde}	0.10 ± 0.18^{cd}	0.07 ± 0.12^{cde}
	Ch 2%	0.35 ± 0.13^{cd}	0.33 ± 0.12^{b}	0.26 ± 0.14^{ab}	0.20 ± 0.12^{abc}	0.17 ± 0.15^{abc}	0.12 ± 0.12^{ab}	0.09 ± 0.15^{abc}
	Control	0.19 ± 0.14^{g}	0.18 ± 0.15^{f}	0.15 ± 0.12^{e}	0.11 ± 0.14^{f}	0.08 ± 0.15^{g}	0.05 ± 0.14^{f}	0.02 ± 0.25^{h}
Cultivars								
	Apple	0.26 ± 0.14^{a}	0.25 ± 0.13^{a}	0.17 ± 0.12^{b}	0.13 ± 0.15^{b}	0.10 ± 0.15^{a}	0.07 ± 0.15^{a}	0.04 ± 0.16^{a}
	Tommy Atkins	0.26 ± 0.15^{a}	0.24 ± 0.15^{b}	0.21 ± 0.12^{a}	0.16 ± 0.14^{a}	0.13 ± 0.13^{b}	0.09 ± 0.14^{a}	0.06 ± 0.16^{a}
Over all	Significance	Ns	*	*	*	*	**	**
	LSD (5%)	0.07	0.06	0.05	0.0391	0.0356	0.0322	0.0314
	CV	13.80	12.23	11.40	13.29	15.86	15.87	15.17

Note: Means followed with the same letter(s) are not significantly different, each column was analyzed separately. Ns: not significant, *: significant ($p < 0.05$), **: highly significant ($p < 0.001$), LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

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Table 5. Effect of coating material on pH of Tommy Atkins and Apple mango after storage.

Variety	Treatment	Days after storage						
		0	5	10	15	20	25	30
Apple	Bw 0.5%	3.07 ± 0.15^{d}	3.46 ± 0.22^{g}	3.54 ± 0.24^{f}	3.61 ± 0.25^{ef}	3.67 ± 0.16^{ef}	3.74 ± 0.21^{fg}	4.52 ± 0.15^{f}
	Bw 1.5%	3.03 ± 0.25^{d}	3.52 ± 0.15^{fg}	3.63 ± 0.25^{ef}	3.70 ± 0.25^{de}	3.76 ± 0.15^{def}	3.82 ± 0.15^{efg}	4.34 ± 0.21^{ef}
	Bw 2%	3.40 ± 0.22^{c}	3.72 ± 0.15^{ef}	3.81 ± 0.24^{de}	3.86 ± 0.15^{cde}	3.95 ± 0.21^{cde}	3.98 ± 0.15^{def}	4.00 ± 0.20^{c}
	Ch 0.5%	2.88 ± 0.15^{d}	3.94 ± 0.25^{bcd}	4.01 ± 0.23^{bcd}	4.05 ± 0.15^{bc}	4.17 ± 0.14^{bc}	4.39 ± 0.25^{cd}	5.15 ± 0.15^{bc}
	Ch 1.5%	3.10 ± 0.25^{d}	3.49 ± 0.15^{g}	3.57 ± 0.15^{f}	3.61 ± 0.21^{ef}	3.71 ± 0.18^{ef}	4.13 ± 0.15^{cde}	5.06 ± 0.15^{c}
	Ch 2%	2.89 ± 0.22^{d}	3.17 ± 0.24^{h}	3.28 ± 0.15^{g}	3.39 ± 0.21^{f}	3.50 ± 0.16^{f}	3.60 ± 0.21^{g}	4.32 ± 0.17^{de}
	Control	3.73 ± 0.15^{ab}	4.11 ± 0.25^{ab}	4.31 ± 0.21^{a}	4.62 ± 0.15^{a}	5.07 ± 0.21^{a}	5.73 ± 0.22^{a}	6.20 ± 0.25^{a}
Tommy Atkins	Bw 0.5%	3.53 ± 0.25^{bc}	3.81 ± 0.15^{cde}	3.90 ± 0.25^{bcd}	4.00 ± 0.25^{bc}	4.11 ± 0.15^{bcd}	4.27 ± 0.25^{cd}	4.71 ± 0.15^{fg}
	Bw 1.5%	3.56 ± 0.22^{abc}	3.91 ± 0.22^{bcde}	4.02 ± 0.15^{bc}	4.11 ± 0.21^{bc}	4.18 ± 0.25^{bc}	4.29 ± 0.15^{cd}	4.31 ± 0.21^{h}
	Bw 2%	3.39 ± 0.25^{c}	3.86 ± 0.2^{cde}	3.90 ± 0.21^{cd}	4.02 ± 0.25^{bc}	4.16 ± 0.15^{bc}	4.26 ± 0.25^{cd}	4.28 ± 0.15^{c}
	Ch 0.5%	3.57 ± 0.15^{abc}	3.73 ± 0.12^{def}	3.80 ± 0.15^{de}	3.92 ± 0.24^{cd}	4.01 ± 0.15^{cde}	4.22 ± 0.20^{cd}	5.00 ± 0.25^{de}
	Ch 1.5%	3.53 ± 0.22^{bc}	3.98 ± 0.15^{bc}	4.11 ± 0.25^{ab}	4.27 ± 0.15^{b}	4.37 ± 0.21^{b}	4.47 ± 0.15^{c}	4.86 ± 0.21^{d}
	Ch 2%	3.41 ± 0.15^{c}	3.74 ± 0.21^{de}	3.81 ± 0.15^{cd}	3.87 ± 0.13^{cde}	4.00 ± 0.15^{cde}	4.20 ± 0.21^{cde}	4.25 ± 0.15^{gh}
	Control	3.79 ± 0.22^{a}	4.25 ± 0.14^{a}	4.31 ± 0.21^{a}	4.68 ± 0.15^{a}	4.97 ± 0.15^{a}	5.23 ± 0.20^{b}	5.39 ± 0.15^{b}
Cultivars								
	Apple	3.54 ± 0.20^{a}	3.90 ± 0.21^{a}	3.98 ± 0.25^{a}	4.12 ± 0.18^{a}	4.26 ± 0.22^{a}	4.42 ± 0.15^{a}	4.82 ± 0.16^{a}
	Tommy Atkins	3.16 ± 0.19^{b}	3.63 ± 0.15^{b}	3.74 ± 0.22^{b}	3.83 ± 0.22^{b}	3.98 ± 0.19^{b}	4.21 ± 0.15^{b}	4.51 ± 0.19^{b}
Over all	Significance	*	**	**	*	*	*	**
	LSD (5%)	0.2405	0.2126	0.2142	0.2843	0.3504	0.3936	0.2791
	CV	4.19	3.47	3.39	4.42	5.24	5.62	3.70

Note: Means followed with the same letter are not significantly different, each column was analyzed separately. *: significant. **: highly significant, LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

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Table 6. Effect of coating material on disease Incidence of Tommy Atkins and Apple mango fruits.

Variety	Waxing	Days after storage			
		15	20	25	30
Apple	Bw 0.5	(22.22) 14.29 ± 0.05^{b}	(35.24) 33.33 ± 0.25^{a}	(39.23) 40 ± 0.25^{abc}	(60) 75 ± 0.25^{b}
	Bw 1.5	(1.15) 0 ± 0.02^{c}	(24.12)16.67 ± 0.03^{c}	(26.56) 20 ± 0.03^{bc}	(45) 50 ± 0.05^{c}
	Bw 2	(1.15) 0 ± 0.01^{c}	(1.15) 0 ± 0.01^{c}	(26.56) 20 ± 0.02^{bc}	(30) 25 ± 0.02^{d}
	Ch 0.5	(32.33) 28.57 ± 0.02^{b}	(33.27) 30.12 ± 0.02^{a}	(39.23) 40 ± 0.03^{abc}	(45) 50 ± 0.05^{c}
	Ch 1.5	(1.15) 0 ± 0.01^{c}	(24.12) 16.67 ± 0.02^{b}	(39.23) 40 ± 0.03^{abc}	(45) 50 ± 0.05^{c}
	Ch 2	(1.15) 0 ± 0.01^{c}	(1.15) 0 ± 0.01^{c}	(26.56) 20 ± 0.02^{bc}	(30) 25 ± 0.03^{d}
	Control	(90) 100 ± 0.06^{a}	(90) 100 ± 0.06^{a}	(90) 100 ± 0.06^{a}	(90) 100 ± 0.06^{a}
Tommy Atkins	Bw 0.5	(22.22) 14.29 ± 0.02^{b}	(26.23) 20 ± 0.020^{a}	(45) 50 ± 0.21^{ab}	(60) 75 ± 0.025^{b}
	Bw 1.5	(1.15) 0 ± 0.02^{c}	(24.12) 16.67 ± 0.05^{c}	(26.56) 20 ± 0.05^{bc}	(45) 50 ± 0.13^{c}
	Bw 2	(1.15) 0 ± 0.01^{c}	(1.15) 0 ± 0.02^{c}	(26.56) 20 ± 0.02^{bc}	(30) 25 ± 0.03^{d}
	Ch 0.5	(22.22) 14.29 ± 0.03^{b}	(35.24) 33.33 ± 0.05^{a}	(39.23) 40 ± 0.05^{abc}	(45) 50 ± 0.05^{c}
	Ch 1.5	(1.15) 0 ± 0.01^{c}	(24.12) 16.67 ± 0.02^{b}	(26.56) 20 ± 0.02^{bc}	(39.23) 40 ± 0.04^{cd}
	Ch 2	(1.15) 0 ± 0.02^{c}	(1.15) 0 ± 0.02^{c}	(26.56) 20 ± 0.04^{bc}	(30) 25 ± 0.04^{d}
	Control	(90) 100 ± 0.05^{a}	(90) 100 ± 0.05^{a}	(90) 100 ± 0.05^{a}	(90) 100 ± 0.05^{a}
Over all	Significant	*	**	**	**
	LSD (5%)	0.0036	0.0036	0.0109	0.0052
	CV	5.47	4.36	11.28	4.38

Note: Means followed with the same letter are not significantly different, each column was analyzed separately. Ns: not significant ($P > 0.05$),*significant, **: highly significant, LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

observed on the control treatments on all days of assessment while, the minimum disease incidence (0%) was observed on 1.5% and 2% beeswax and chitosan treated mango fruits on 15th day of storage. Both wax coatings showed significant ($p < 0.05$) effects on disease incidence of mango fruits on the first three weeks of storage (15th, 20th, 25th and 30th) and later on showed few symptoms.

The disease incidence on mango fruits increased with the advancement of time and almost all treated mango fruits showed the disease symptom after twenty days of storage and all of the control fruits showed the symptom after tenth days of storage. The present study is in line with findings of El-Ghaouth et al. (1992) who reported that chitosan coating prevented attack of tomatoes by *Penicillium* spp., *Aspergillus* spp., *Rhizopus stolonifer* and *Botrytis cinerea*. The investigation by Eissa (2007) also reported that wax coating extend the shelf-life by limiting the growth of fungi, and decreased the spoilage without affecting ripening characteristics of fruits.

3.6. Disease severity

Table 7 shows disease severity values as affected by variety, waxing materials and their concentrations. Fruit disease severity index was found to be 100%, 40% and 43% for control, 2% beeswax and 2% chitosan coated fruits respectively after 30 days of storage period. Almost fruit disease severity index was similar (40%) in both 2% beeswax and chitosan coated fruits with a higher fruit disease index of 60% and 80% respectively after 25 days of storage.

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Table 7. Effect of coating material on disease Severity of Tommy Atkins and Apple mango fruits.

Variety	Waxing	Days after storage			
		15	20	25	30
Apple	Bw 0.5	23.33 ± 0.12^{b}	31.10 ± 0.20^{b}	38.87 ± 0.21^{bc}	46.64 ± 0.22^{b}
	Bw 1.5	19.93 ± 0.16^{bc}	27.7 ± 0.19^{b}	35.47 ± 0.21^{cd}	43.24 ± 0.24^{bc}
	Bw 2	16.67 ± 0.13^{c}	24.44 ± 0.18^{b}	32.21 ± 0.205^{d}	39.98 ± 0.25^{d}
	Ch 0.5	20.55 ± 0.20^{bc}	28.32 ± 0.20^{b}	36.09 ± 0.22^{ab}	43.86 ± 0.25^{bc}
	Ch 1.5	26.12 ± 0.12^{b}	33.89 ± 0.20^{b}	41.66 ± 0.22^{b}	49.43 ± 0.23^{b}
	Ch 2	20.55 ± 0.15^{c}	28.32 ± 0.19^{b}	36.09 ± 0.20^{c}	43.86 ± 0.27^{bc}
	Control	63.89 ± 0.27^{a}	71.66 ± 0.25^{a}	79.43 ± 0.28^{a}	100 ± 0.32^{a}
Tommy Atkins	Bw 0.5	23.82 ± 0.17^{b}	31.59 ± 0.19^{b}	39.36 ± 0.20^{cd}	47.13 ± 0.25^{b}
	Bw 1.5	18.33 ± 0.13^{bc}	26.10 ± 0.20^{b}	33.87 ± 0.21^{d}	41.64 ± 0.22^{d}
	Bw 2	16.67 ± 0.15^{c}	24.44 ± 0.17^{b}	32.21 ± 0.22^{d}	39.98 ± 0.25^{d}
	Ch 0.5	23.82 ± 0.14^{b}	31.59 ± 0.16^{b}	39.36 ± 0.20^{b}	47.13 ± 0.24^{b}
	Ch 1.5	21.67 ± 0.15^{bc}	29.44 ± 0.20^{b}	37.21 ± 0.22^{c}	44.98 ± 0.24^{bc}
	Ch 2	19.93 ± 0.15^{bc}	27.70 ± 0.18^{b}	35.47 ± 0.21^{cd}	43.24 ± 0.25^{bc}
	Control	56.13 ± 0.20^{a}	63.90 ± 0.25^{a}	71.67 ± 0.27^{a}	100 ± 0.28^{a}
Over all	Significant	*	*	**	*
	LSD (5%)	0.0089	0.0115	0.0115	0.0089
	CV	11.17	11.41	11.54	7.00

Note: Means followed with the same letter are not significantly different, each column was analyzed separately. *: significant, **: highly significant, LSD: Least significant difference, Ch: chitosan; Bw: beeswax.

Most of the symptoms appeared on the control fruits after 8 days of storage and after 25 days most of the mango fruits were spoiled due to severe disease infection. The effect of beeswax and chitosan coating treatment had a significant ($p < 0.005$) effect in all evaluated days and there is no significant difference between the two varieties of 'Apple' and 'Tommy Atkins' mango fruits used. The percentage disease index on mango reached up to 100% (6 score), after 30 days of storage in the control fruits.

The present study has similar findings with Lam and Diep (2003) who reported that chitosan coating limit the growth of fungi, and decrease the spoilage without affecting the ripening characteristics of fruit. These observations were also supported by Bibi and Baloch (2014) who reported that wastage percentage was decreased in coated fruit due to the fact that beeswax reduces fruits ripening process and attack of microorganisms. Similar report was also made by Covas (2008) who reported that coating materials were also antioxidant and antimicrobial as a result the decay process and attack of diseases were reduced and resulting in longer shelf life.

3.7. Storage life

The treatment of 0.5%, 1.5 % and 2% of fruits treated in both edible coating caused the extension of storage life of mango fruits tested under the current study by 20, 25 and 30 days respectively, while control fruits was stayed only for 15 days (Fig. 1).

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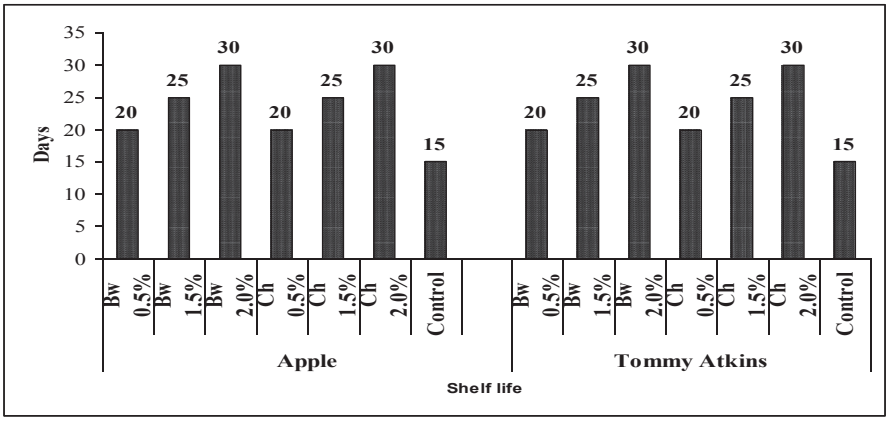

Fig. 1. Effect of beeswax and chitosan coating with different concentration on Storage life of Apple and Tommy A.

Generally, the fruits treated with 2% beeswax and chitosan showed higher shelf-life index value (30days) as compared to other treatments. This could be correlated with other quality attributes as the shelf-life extension is a cumulative effect of maintaining different quality attributes. The present results were similar with the studies of Penchaiya et al. (2006) who reported that shelf-life of mango fruits was extended with the application of edible coating.

4. Conclusions

In an effort to maintain the freshness and shelf-life of mango fruits, edible coating at different concentration were tested and demonstrated great potential to be used in maintaining the overall quality compared with untreated control. The study indicated that beeswax and chitosan coating effectively delayed ripening of both 'Apple' and 'Tommy Atkins' mango fruits as indicated by reduction of weight loss, the retention of firmness. Furthermore, the change in TA and TSS in the mango fruits were significantly inhibited by the beeswax and chitosan coating compared with untreated control. Both edible coatings with different concentrations not only maintained the freshness of the fruits during first three weeks of storage but also controlled the occurrence of disease. Although every coating has its impact on the quality and shelf life of the fruits beeswax at 2% outweighs other treatments in terms of maintaining the freshness and controlling the occurrence of disease. Therefore, mango handlers could easily adapt the technology to treat fresh mangoes in order to transport to long distance without affecting its quality if treated carefully with appropriate type of wax coat and concentration.

Declarations

Author contribution statement

Abonesh Eshetu, Chala G. Kuyu: Performed the experiments; Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Ali M. Ibrahim, Sirawdink F. Forsido: Conceived and designed the experiments; Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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